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Spectroscopic investigation of unstudied southern PNe*

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Abstract. We present a spectroscopic investigation of two hitherto unstudied galactic planetary nebulae (MeWe 1-10 and MeWe 1-11) and one candidate object (MeWe 2-5). The candidate object clearly has been identified as a bipolar hourglass shaped PN. The galactic foreground extinction was derived and using photoionization models with CLOUDY the two round objects were classified as highly evolved nebulae.

Key words. planetary nebulae: individual: MeWe 1-10, MeWe 1-11, MeWe 2-5

1. Introduction

The two PNe, MeWe 1-10, MeWe 1-11 and the candidate object MeWe 2-5 were discovered on ESO-R film copies during a systematic survey by Melmer & Weinberger (1990). They classified the first two objects on the basis of morphology as PNe and the last one to be a candidate. They have never been studied individually. The same classification then was used by Acker et al. (1992). The only published measurements are radial velocities for MeWe 1-10 and MeWe 1-11 in the context of a survey of PNe to study the galactic population (Durand et al. 1998; Beaulieu et al. 1999).
We present here a spectroscopic investigation and photoionization models of these targets.

Planetary nebulae (PNe) have for a long time been known as representing an inescapable bottleneck in late stellar evolution for stars of intermediate masses. Many studies focus either on a few well–known prototypes or only give a very coarse overview (see the statistics in Acker 1997). We contribute to the sample of individual studies to get better statistics for larger PNe samples. A number of the most evolved of them were used as a probe of PNe–interstellar matter (ISM) interaction (Rauch et al. 1999; Kerber et al. 2000a, 2000b). The spectroscopy presented here shows that MeWe 1-10 and 1-11 also might be good probes for a detailed deeper study of the ISM interaction, which is beyond the scope of this research note.

* Based on observations collected at the European Southern Observatory, La Silla

2. Observations and data reduction

The data was obtained on July 16$^{\rm th}$ 1998 using the Danish 1.54 m telescope with the DFOSC spectrograph at ESO La Silla, Chile. A LORAL 2k x 2k CCD detector and Grism #4 with a resolution of 3.1 nm/pixel and a usable range from 4500 nm to 7000 nm were attached. The calibration was done using usual procedure in MIDAS and the calibration data from the DFOSC manual. The standard star EG 274 (Hamuy et al. 1992) was used for flux calibration. For slit centering purposes a narrow band [O III] image was taken before each spectrum.

3. Results

3.1. Astrometry and cross-identification

To obtain accurate astrometry of the PNe the narrow band [O III] image was used. In the case of MeWe 1-10 and MeWe 1-11 the stars selected by Melmer & Weinberger (1990) as candidates for the central stars of the PN (CSPNe) were selected. Our spectra indeed show them as very hot blue objects with very weak lines typical of CSPNe. For MeWe 2-5 the geometric center of the central bar at the [OIII] direct imaging frame was selected. The DFOSC has, according to the manual, a resolution of $0.''39$ per pixel. We measure $0.''3929 \pm 0.''00046$. The FWHM on the images used for the astrometry were within the range of $2.''36$ to $3.''54$. We used only the central part of the image with a radius of $2'$ around the target. This provides us with a highly distortion–free image. Astrometric calibrators were taken from the USNO CCD Astrometric

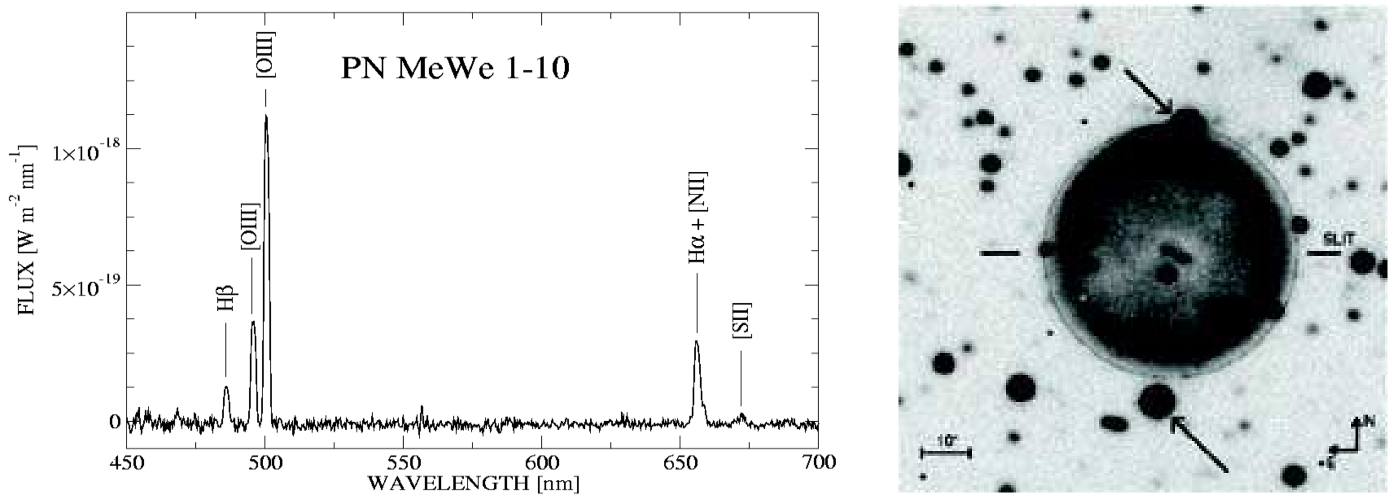


Fig. 1. Spectrum (left) and image (right) of PN MeWe 1-10. The exposure time was 900 seconds for the spectrum as well as for the image. The arrows in the image mark the stars used as astrometric calibrators. The images are given in sky orientation (E is left, N is up). The inner circle encloses the central star of the PN and the outer circle shows the almost perfectly round shape of this nebula. The NE enhancement might be due to ISM interaction, but as the slit of the spectrum does not cover this region, we cannot be sure. The offset of the outer ring with respect to the CSPN strongly encourages this interpretation.

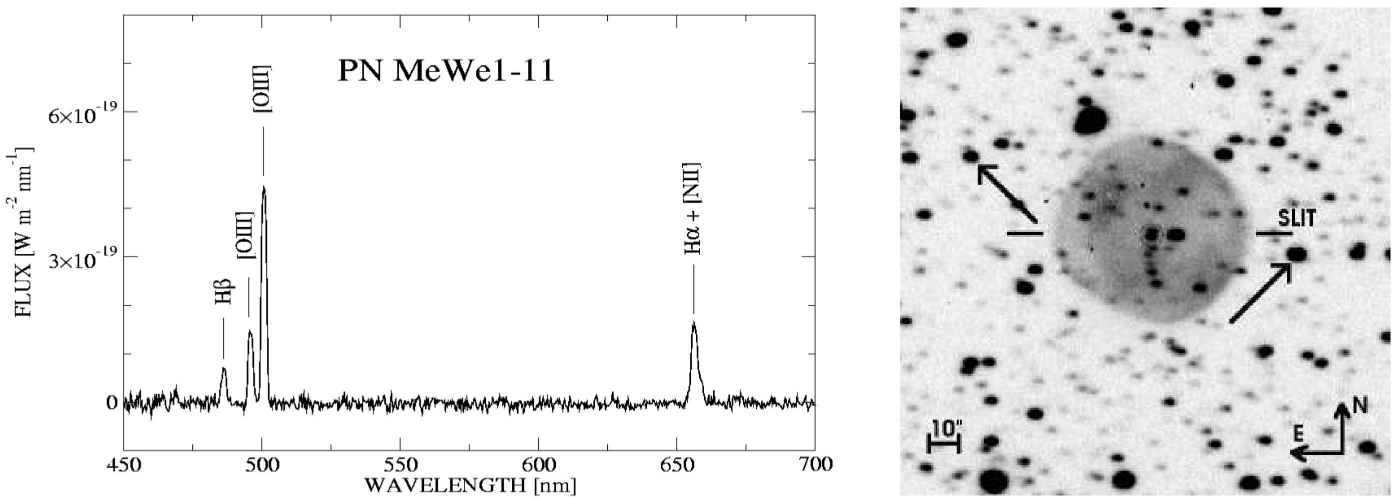
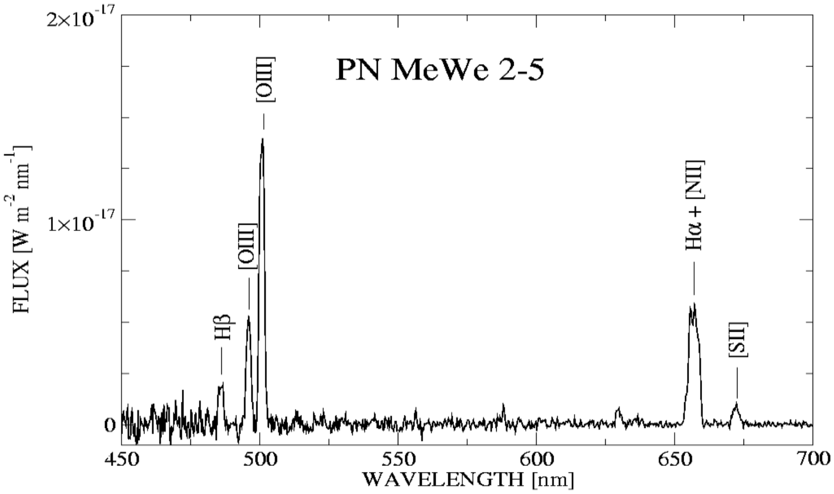


Fig. 2. Spectrum (left) and image (right) of PN MeWe 1-11. The exposure times were 900 seconds for the spectrum and for the image. The marks are as described in Fig. 1. The western edge is clearly enhanced. This is most likely due to ISM interaction. But including the somewhat weaker SE dip implies that it might be a signature of a cylindrical structure (see Fig. 5).

Catalogue (Zacharias et al. 2000). This catalogue contains southern sources with an accuracy of about 20 mas in the red magnitude range $10^{\mathrm{m}} < m < 14^{\mathrm{m}}$ and still has an accuracy of about 70 mas at the limit of 16^{m}. We used the two most nearby stars for each target to obtain the astrometry (marked in Fig. 1; Fig. 2 and Fig. 3). The results are presented in Tab. 1. According to Andersen & Kimeswenger (2001) the error of our coordinates is assumed to be 110 mas. Thus our coordinates are more accurate than the one given by Kimeswenger (2001) that had an rms of about $1''$ and had due to the GSC reference frame up to $2''$ of systematic effects.

3.2. Spectroscopy

All three objects are not associated with a known radio survey source nor have IRAS counterparts been found. The relative errors of the individual lines and the error of the line ratios were estimated using different regions of the spectrum along the slit and the accuracy of the standard star. As the variations lie within a few percent, a conservative estimate gives an error of 10-15% for the line ratios. Since the Hα and [N II] lines are not detached in our spectra, we had to deconvolve them. We derived the line profile from the isolated night-sky-line at 630 nm. Using this profile, the known positions of the lines and the



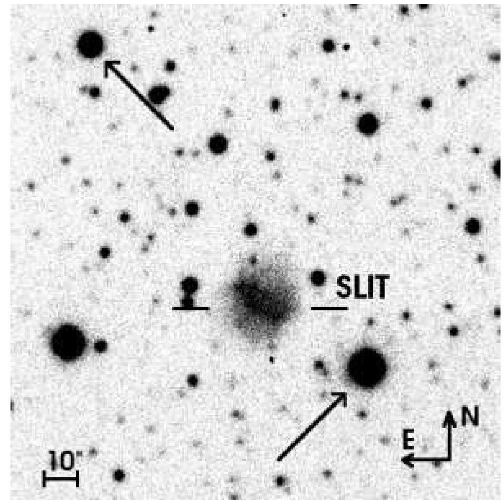


Fig. 3. Spectrum (left) and image (right) of PN MeWe 2-5. The exposure times were 900 seconds for the spectrum and for the image. The marks are as described in Fig. 1.

Table 1. Basic data for the PNe investigated

Name	PN G (according Acker et al. 1992)	GPN (according Kimeswenger 2001)	α_{J2000}	δ_{J2000}	size [″]	stat. dist. [kpc]	radius [pc]
MeWe 1-10	PN G336.9-11.5	GPN G336.98-11.58	$17^h34^m28^s.18$	-54°28′57″.4	76″	2.9	0.53
MeWe 1-11	PN G345.3-10.2	GPN G345.32-10.21	$17^h52^m47^s.09$	-46°42′00″.4	69″	3.1	0.51
MeWe 2-5		GPN G340.93+03.75	$16^h34^m49^s.60$	-42°03′45″.1	28″	8.0	0.54

quantum mechanically fixed line ratio of the [N II] lines a restricted fit, only having the ratio $H\alpha/\sum$[N II] as a free parameter, was applied. The resulting fit is given in Fig. 4. The fit quality gives an error estimate comparable to that of the isolated lines for Hα and [N II]$_{658.4}$.

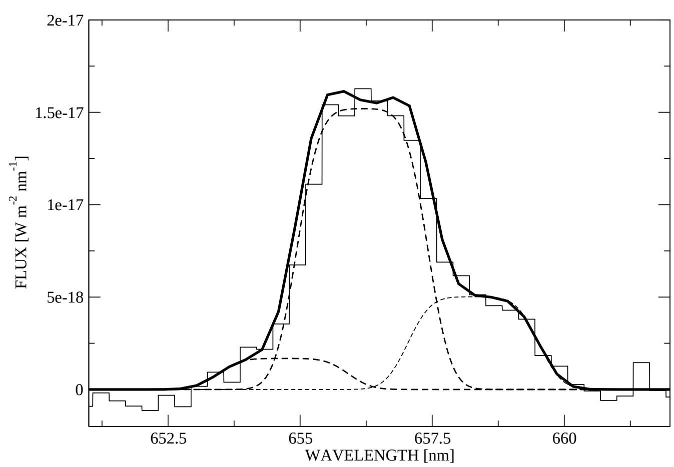


Fig. 4. The "deconvolution" of the Hα and [N II] lines in case of We 1-11. The thin line gives the data, the thin dashed lines the individual lines of the applied fit, using the profile of a nearby night-sky-line, using fixed positions and a fixed ratio of [N II]$_{658.4}$/[N II]$_{654.8}$. The thick line gives the total fit.

To deredden the frames we used the interstellar extinction curve of Savage & Mathis (1979). The error estimate for the lines results in an error in the reddening. The statistical distance and the radius of the nebulae have been calculated from the 5 GHz surface brightness data (Schneider & Buckley 1996). We estimated the 5 GHz data from the Hβ surface brightness along the slit (Cahn et al. 1992), because no radio data were available.

MeWe 1-10 (Fig. 1, Tab. 2) is a roughly round PN and its central star is well centered. From the Balmer decrement we find considerable interstellar reddening of E(B-V) = $0^m.262$, as is not unexpected for this galactic region. The ratio of the [S II] doublet, which is very faint and also not well detached, indicates a density of $\leq 200\ cm^{-3}$ clearly showing that the object is in a late stage of evolution.

Table 2. PN MeWe 1-10 Line identifications

Line [nm]	observation (dereddened)	model
$H\beta_{486.1}$	100	100
[OIII]$_{495.9}$	303	311
[OIII]$_{500.7}$	927	897
[NII]$_{654.8}$	18	18
$H\alpha_{656.3}$	287	287
[NII]$_{658.4}$	53	52
[SII]$_{671.7}$	18	28
[SII]$_{673.1}$	12	-
E(B-V)	$0^m.26 \pm 0^m.05$	
CS temp. [K]		69000±3000
CS lum. [$L_\odot$]		350±100

MeWe 1-11 (Fig. 2, Tab. 3) is a box-shaped PN. It shows a pronounced brightness enhancement to the north-west in [N II], that is less prominent in the [O III] image (Fig. 2). A possible explanation for this peculiarity is that MeWe 1-11 is interacting with the interstellar medium. As shown in Fig. 5 the spectrum changes there significantly towards partly deionized stages. While the ionization stage, defined by [OIII] / H_β, does not change [NII] and [SII] are enhanced abruptly. This is typical of ISM interacting regions (Furlan 1999; Kerber et al. 2000b). In the diagnostic diagram of Garcia Lario et al. (1991) it strongly moves towards the regions of shocked gas (see e.g. Zanin & Weinberger 1997), but it still carries the signature of a mainly photoionized PN. The Balmer decrement gives no interstellar reddening. As the line of sight leaves the galactic plane and as the Gould Belt clouds are above the plane in this direction this low reddening is possible. The [S II] doublet is not detectable, but we estimate from the surface brightness, that is comparable to that of MeWe 1-10 at a similar distance, that the density is also $\leq 200\ cm^{-3}$.

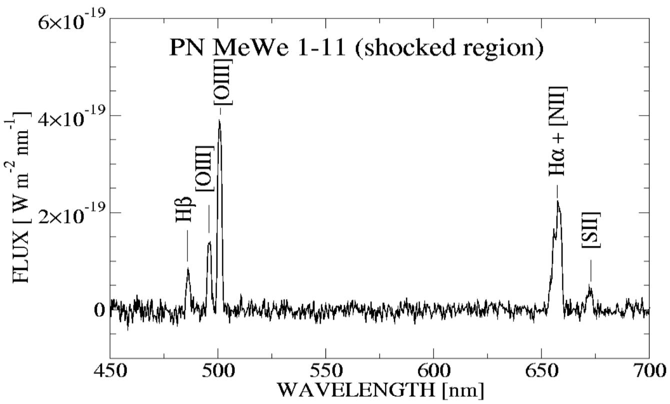


Fig. 5. The spectrum of PN MeWe 1-11 at the western edge. The spectrum changes abruptly with respect to the other parts of the nebula (see text).

Table 3. PN MeWe 1-11 Line identifications

Line [nm]	main region (deredd.)	western edge (deredd.)	model
$H\beta_{486.1}$	100	100	100
$[OIII]_{495.9}$	221	205	239
$[OIII]_{500.7}$	690	591	689
$[NII]_{654.8}$	30	115	30
$H\alpha_{656.3}$	269	222	287
$[NII]_{658.4}$	89	344	89
$[SII]_{671.7}$	-	51	-
$[SII]_{673.1}$	-	34	-
E(B-V)	$\approx 0\overset{m}{.}0$		
CS temp. [K]			70000±5000
CS lum. [$L_\odot$]			206±100

MeWe 2-5 (Fig. 3,Tab. 4) is a bipolar PN. The interstellar reddening has been found to be E(B-V) = $1\overset{m}{.}214$. According to the lower galactic latitude of the object, this is to be expected. The ratio of the [S II] doublet, also very faint and not well detached in this object, indicates a density of $\leq 200\ cm^{-3}$. This indicates that the object is in a late stage of evolution, like the other two nebulae. The features at 589 nm and 630 nm seem to be relicts of the night-sky-lines.

Table 4. PN MeWe 2-5 Line identifications

Line [nm]	observation (dereddened)
$H\beta_{486.1}$	100
$[OIII]_{495.9}$	251
$[OIII]_{500.7}$	735
$[NII]_{654.8}$	89
$H\alpha_{656.3}$	279
$[NII]_{658.4}$	265
$[SII]_{671.7}$	42
$[SII]_{673.1}$	29
E(B-V)	$1\overset{m}{.}21 \pm 0\overset{m}{.}05$

4. Photoionisation model

To get an idea of the temperature and the luminosity of the central star we modelled these nebulae with the CLOUDY code (Ferland 1996). The abundances were used as in the standard PN of CLOUDY. Only sulphur had to be lowered to the solar value. Since the [S II] doublet is very faint we based our modelling on the relative line fluxes of $[O\,III]_{500.7}$ and $[N\,II]_{658.4}$. We used the NLTE central star models of Rauch (1997, 2003). As found by Armsdorfer et al. (2002) the use of real stellar photosphere models is critical for the parameters of the central stars. Assuming that the density is between 100 and 200 cm^{-3} according to the observed ratio $\frac{[S\,II]_{671.7}}{[S\,II]_{673.1}}$, we used densities of 100, 150 and 200 cm^{-3}. Since the radius calculated by the method of Schneider & Buckley (1996) is quite large, we varied also the radius from 0.5 to 1 times the calculated radius (resp. varied the distance). Supposing a constant expansion velocity of the objects of 20 to 30 km/s, typical for such round objects (Weinberger 1989), we are able to calculate the age of the nebulae from their radii. Thus it was possible to compare the luminosity and the radii of our simulations with models of evolutionary tracks of central stars of PNe (Bloecker 1995, Vassiliadis & Wood 1994). This comparison indicates that the radii, and due to this also the distance, should be smaller by a factor of two from the calculation above. Also the density seems to be rather 100 cm^{-3} than 200 cm^{-3}. In Fig. 6 the result of one of these models is shown. Because PN MeWe 2-5 is a bipolar nebula, CLOUDY is not a proper tool to model this object. We thus decided not to model it.

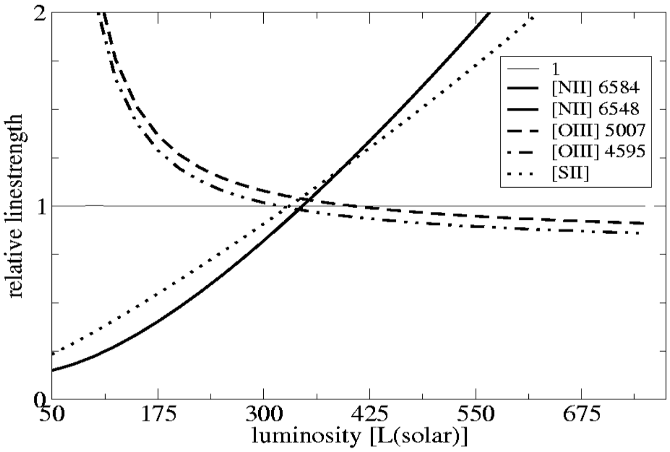


Fig. 6. The fit of a CLOUDY model (MeWe 1-10). On the abscissa is the luminosity in units of $[L_\odot]$ and on the ordinate the ratio of $\frac{\text{linestrenght(observed)}}{\text{linestrength(modeled)}}$.

5. Conclusion

We have spectroscopically confirmed the nature of three PNe, especially of the possible PN MeWe 2-5. Even this small sample already shows that each PN is unique. In particular the old, extended PNe found in the optical surveys tend to be intresting due to their late evolutionary stage; for an ever–increasing number of these PNe, signs of an interaction with the ISM are being discovered.

The photoionisation models suggest a significantly smaller distance to the objects than those found using statistical distances.

The nebulae MeWe 1-10 and MeWe 1-11 lie below the domain of the tracks from Bloecker (1995) and Vassiliadis & Wood (1994). This results in low mass CSPN and thus suggests low mass progenitors. Our model does not lead us to a low abundance of at least CNO elements. This thus does not support the hypothesis of Soker (2002) that round PNe may be formed only from low abundance progenitors.

Further detailed high-resolution spectroscopic investigations of these central stars, so as to be able to model them as in Napiwotzki (1999 & 2001) are strongly encouraged to fix the CSPN parameters. This then will allow us to study the nebula in more detail by fixing parameters like $T_{\rm CSPN}$ and distance.

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